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(54) **GRID ARRAY CONNECTION DEVICE AND METHOD**

(71) Applicant: **INTEL CORPORATION**, Santa Clara, CA (US)

(72) Inventors: **Munehiro Toyama**, Tsukuba (JP); **Siew Fong Tai**, Selangor (MY); **Kian Sin Sim**, Penang (MY); **Charan K. Gurumurthy**, Gilbert, AZ (US); **Tamil Sely Selvamuniandy**, Chandler, AZ (US)

(73) Assignee: **INTEL CORPORATION**, Santa Clara, CA (US)

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*Primary Examiner* — Zandra Smith

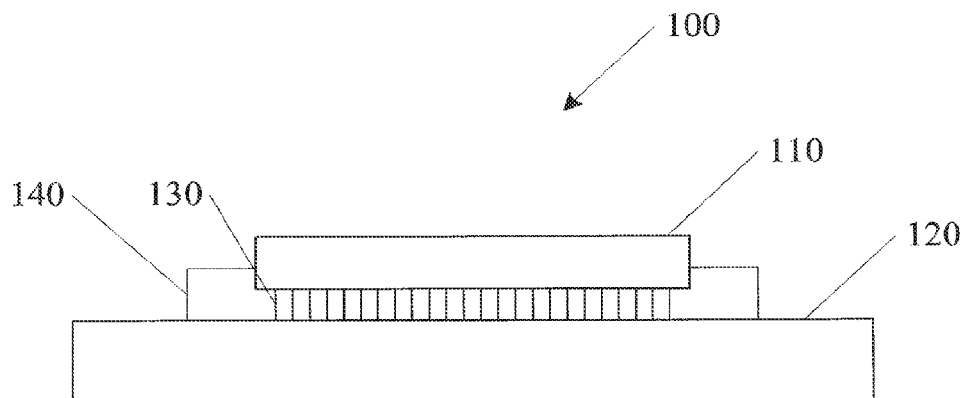
*Assistant Examiner* — Andre' C Stevenson

(74) *Attorney, Agent, or Firm* — Schwabe, Williamson & Wyatt, P.C.

(57) **ABSTRACT**

A method and device for input/output connections is provided. Devices and methods for connection structure are shown with improved mechanical properties such as hardness and abrasion resistance. Land grid array structures are provided that are less expensive to manufacture due to reductions in material cost such as gold. Ball grid array structures are provided with improved resistance to corrosion during fabrication. Ball grid array structures are also provided with improved mechanical properties resulting in improved shock testing results.

**10 Claims, 6 Drawing Sheets**



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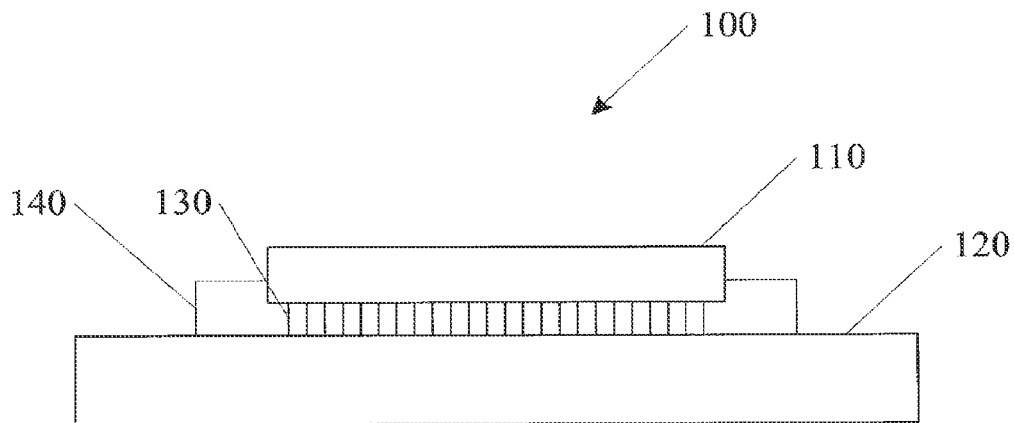
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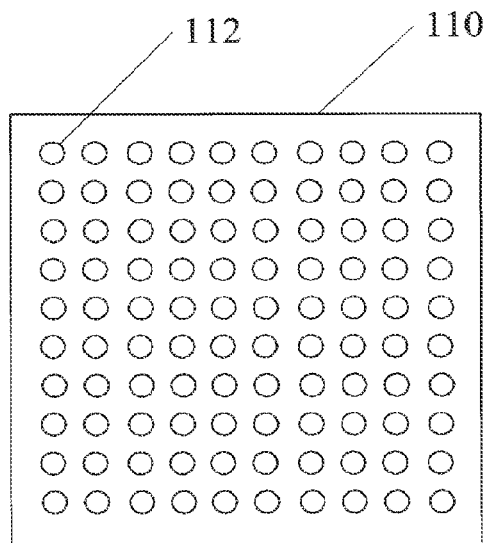
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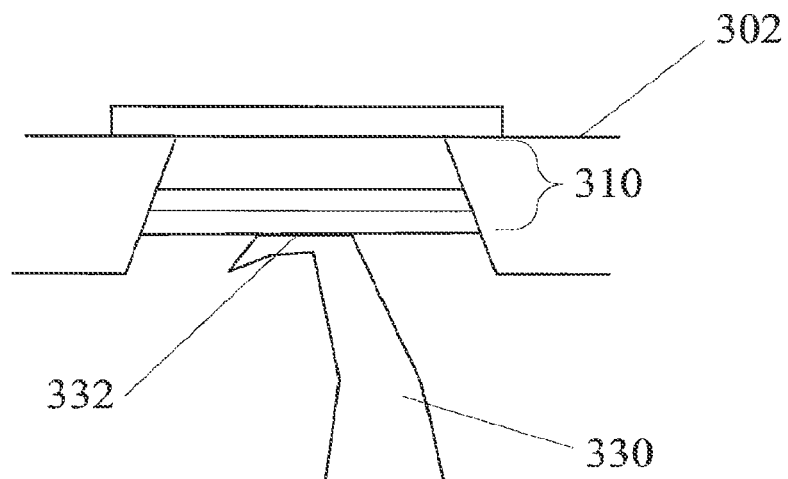
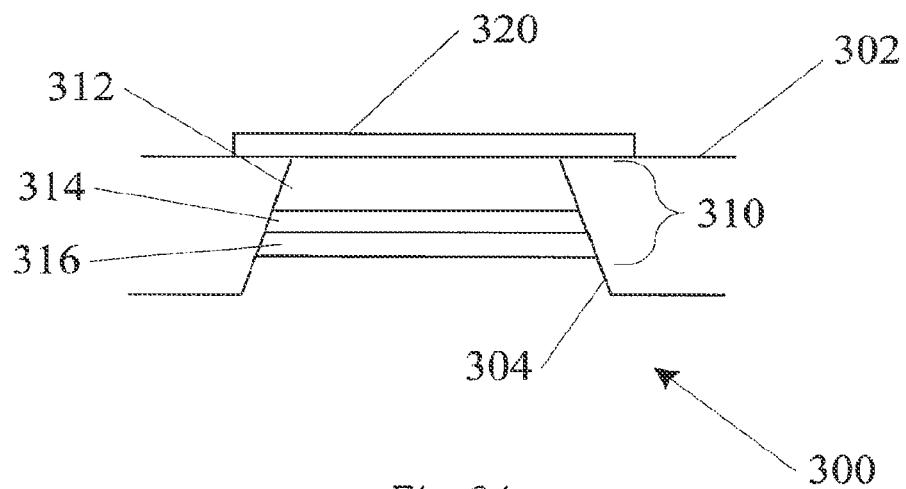
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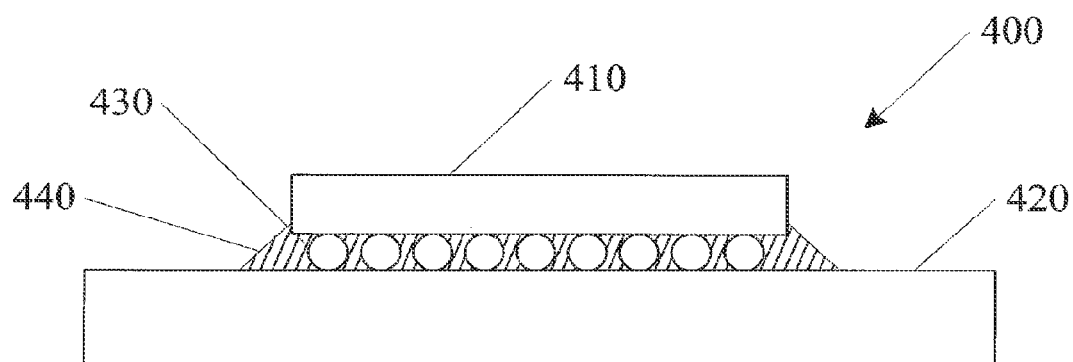


*Fig. 1*

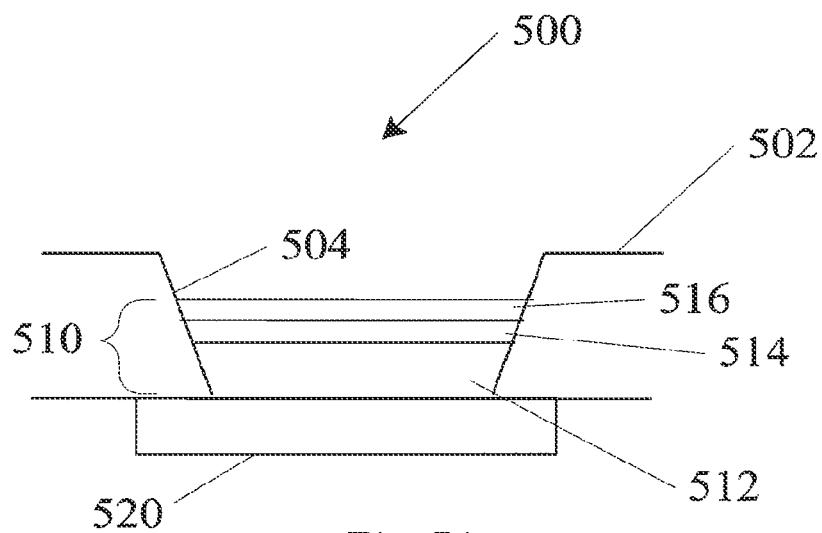


*Fig. 2*

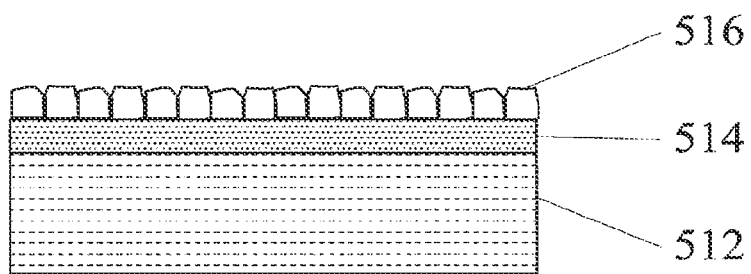




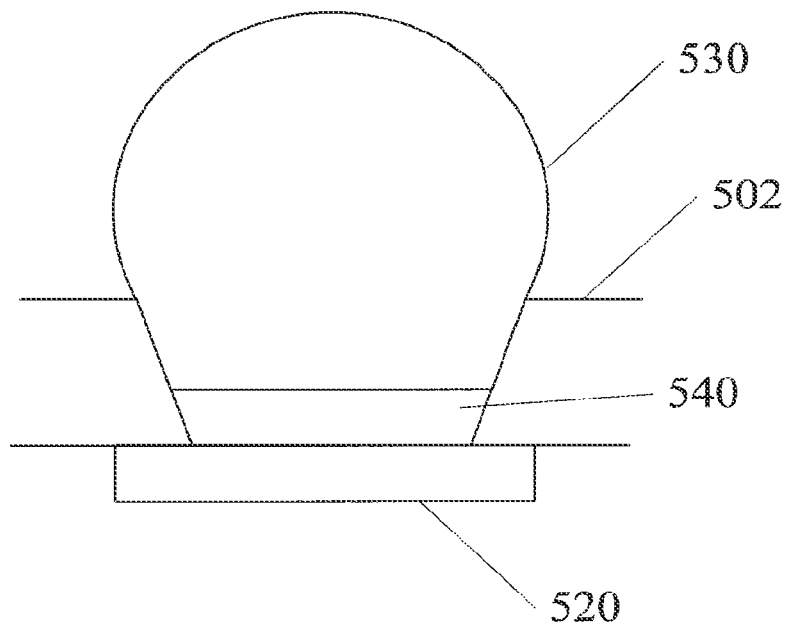
*Fig. 4*



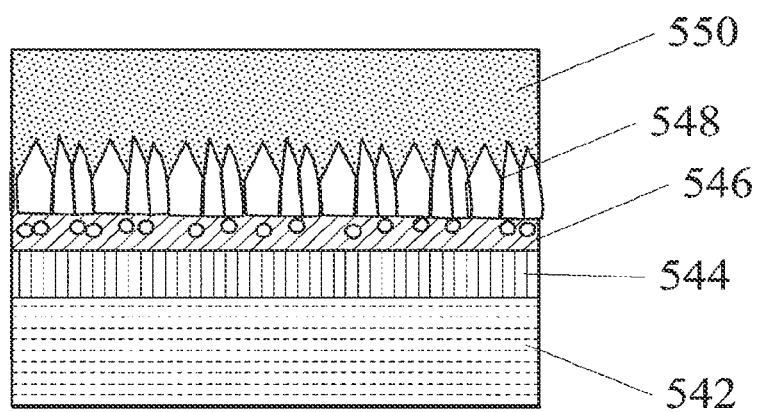
*Fig. 5A*



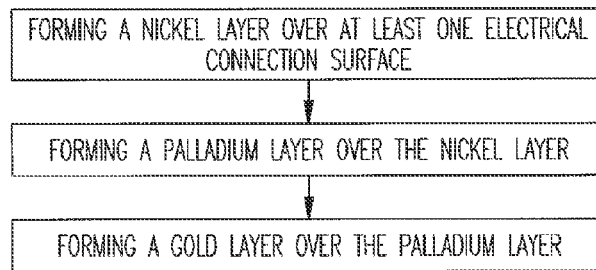
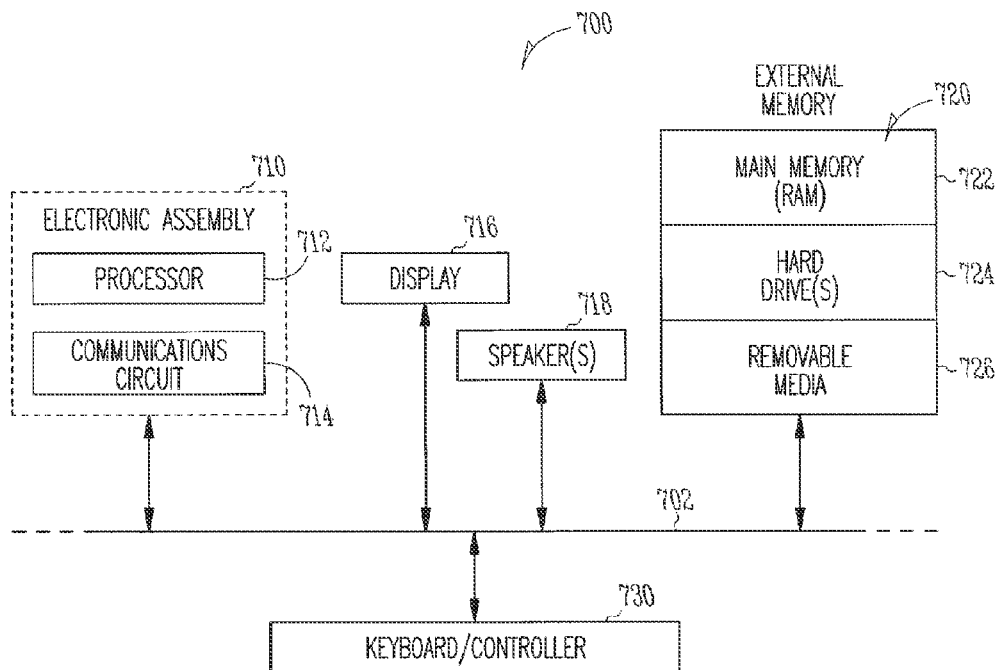
*Fig. 5B*



*Fig. 5C*



*Fig. 5D*

*Fig. 6**Fig. 7*



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**GRID ARRAY CONNECTION DEVICE AND METHOD****CROSS REFERENCE TO RELATED APPLICATIONS**

This application is a continuation of divisional U.S. application Ser. No. 13/071,841, entitled "GRID ARRAY CONNECTION DEVICE AND METHOD," filed Mar. 25, 2011, which is a divisional of U.S. application Ser. No. 12/714,310, filed Feb. 26, 2010, now issued as U.S. Pat. No. 7,915,060, which is a divisional of U.S. application Ser. No. 11/167,922, filed Jun. 27, 2005, now issued as U.S. Pat. No. 7,670,951, the entire contents and disclosures of which are hereby incorporated by reference in their entireties.

**TECHNICAL FIELD**

The present invention relates generally to electronic connection structures. In particular, the present invention relates to devices and methods for grid array connection structures between chip packages and circuit boards.

**BACKGROUND**

Semiconductor chips such as processor chips are housed in chip packages, which are subsequently attached to circuit boards in the manufacture of a number of electronic devices. These devices, include personal computers, handheld computers, mobile telephones, and other numerous information processing devices. One common configuration of input/output connections between chip packages and adjacent circuit boards includes grid array connection structures. Examples of such connection structures include land grid array structures and ball grid array structures.

There are a number of design concerns that are taken into account when forming grid arrays. High mechanical strength and reliability of the grid array connections are desirable. Some devices, for example mobile telephones, are frequently subject to high shock if a user drops their telephone. Other design concerns include ease of manufacturability, and low manufacturing cost.

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 illustrates a chip assembly according to one embodiment of the invention.

FIG. 2 illustrates an input/output grid array according to one embodiment of the invention.

FIG. 3A illustrates an input/output structure according to one embodiment of the invention.

FIG. 3B illustrates an input/output interface according to one embodiment of the invention.

FIG. 4 illustrates a chip assembly according to one embodiment of the invention.

FIG. 5A illustrates an input/output structure in process according to one embodiment of the invention.

FIG. 5B illustrates a microstructure of a portion of an input/output structure in process according to one embodiment of the invention.

FIG. 5C illustrates an input/output structure according to one embodiment of the invention.

FIG. 5D illustrates a microstructure of a portion of an input/output structure according to one embodiment of the invention.

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FIG. 6 illustrates a method of forming a grid array connection structure according to one embodiment of the invention.

FIG. 7 illustrates an electronic system according to one embodiment of the invention.

**DETAILED DESCRIPTION**

In the following detailed description of the invention reference is made to the accompanying drawings which form a part hereof, and in which are shown, by way of illustration, specific embodiments in which the invention may be practiced. In the drawings, like numerals describe substantially similar components throughout the several views. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention. Other embodiments may be utilized, and structural, logical, and electrical changes, etc. may be made, without departing from the scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the invention should be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. The drawings are not drawn to scale unless specifically noted.

FIG. 1 shows a chip assembly 100. A chip package 110 is shown mounted to an adjacent circuit board 120. In one embodiment, as shown in FIG. 1, a grid array socket 140 is included with a number of input/output connections 130 located between the chip package 110 and the circuit board 120. In one embodiment, the grid array socket 140 includes a land grid array socket.

FIG. 2 shows a bottom side of the chip package 110. A mating half 112 of a number of chip connection structures is shown on the chip package 110. In one embodiment, the mating halves 112 include land grid array pad surfaces. In one embodiment, the mating halves 112 include ball grid array structures such as solder balls. In one embodiment, mating halves 112 make up a portion of input/output connections 130 as shown in FIG. 1.

FIG. 3A shows a land grid array structure 300. In one embodiment, the land grid array structure is included in at least one of the mating halves 112 on a chip package 110 as shown in FIG. 2. As will be discussed in more detail below, in one embodiment, an input/output connection between a chip package and an adjacent circuit board includes a land grid array structure 300 and a land grid array pin (330 in FIG. 3B) that forms an electrical contact with the land grid array structure 300.

FIG. 3A shows a portion of a chip package 302 with an electrical connection structure 320. In one embodiment, the electrical connection structure 320 is located adjacent to an opening 304 in the chip package 302. In one embodiment, the electrical connection structure 320 includes a metallic connection surface, for example a copper or copper containing surface. Further shown in FIG. 3A are interface layers 310. A first layer 312, a second layer 314, and a third layer 316 are shown in FIG. 3A.

In one embodiment the first layer 312 includes nickel. In one embodiment the first layer 312 includes nickel and phosphorous. In one embodiment, the nickel in the first layer 312 is deposited on the electrical connection structure 320 using electroless deposition techniques. In one embodiment, the electroless deposition uses a chemical reaction to deposit the first layer 312, which results in an alloy of nickel and phosphorous deposited as the first layer 312. In one embodiment, the first layer is deposited to a thickness of between 5 and 8  $\mu\text{m}$ .

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In one embodiment, the second layer **314** includes palladium. In one embodiment, the second layer includes palladium and phosphorous. In one embodiment, the palladium in the second layer **314** is deposited on the first layer **312** using electroless deposition techniques. In one embodiment, the electroless deposition uses a chemical reaction to deposit the second layer **314**, which results in an alloy of palladium and phosphorous deposited as the second layer **314**.

In one embodiment, the second layer **314** is deposited to a thickness of approximately 100 nm. In one embodiment, the second layer is substantially amorphous. In one embodiment, the second layer is substantially amorphous on a nanometer scale dimension. Advantages of a amorphous microstructure include increased hardness over alternative crystalline structures. Increased hardness allows a deposited layer to be deposited thinner than alternative crystalline layers, while maintaining desired mechanical characteristics. If desired, an amorphous layer can be deposited to similar thicknesses of crystalline layers with improved mechanical characteristics. In one embodiment, the amorphous microstructure is substantially non-porous. A non-porous microstructure provides a further advantage of a continuous barrier layer over underlying structure such as the first layer **312**. Continuous, or non-porous layers help to prevent corrosion of underlying structure such as nickel in an embodiment of the first layer **312**.

In one embodiment, the third layer **316** includes gold. In one embodiment, the gold in the third layer **316** is deposited on the second layer **314** using electroless deposition techniques. In one embodiment, the electroless deposition uses a gold cyanide solution to provide a chemical reaction that deposits the gold in the third layer **316**. In one embodiment, the third layer **316** is deposited to a thickness of approximately 50-80 nm.

Embodiments of the interface layers **310** as described above include a number of advantages. As described above, embodiments of the second layer **314** are deposited with an amorphous microstructure that provides improved mechanical characteristics. Further, embodiments of the second layer **314** provide improved corrosion resistance. These and other characteristics of the interface layers **310** allow a thinner deposition of gold in the third layer **316** as described above. A thinner gold layer allows a substantial price reduction in a grid array connection structure. Further, a thin gold layer such as 50-80 nm provides a finer grain structure than previous thicker gold layer such as 350 nm or more. The finer grain structure of present embodiments further enhances mechanical properties such as high wear resistance.

FIG. 3B shows an example of a pin **330** contacting the interface layers **310** of a grid connection structure **300** as described in embodiments above. A contact interface **332** is formed between the pin **330** and the interface layers **310** allowing electrical conduction and transfer of information from, for example, a chip package and a circuit board. Using embodiments of a grid connection structure **300** as described above, increase reliability is achieved due to improved mechanical characteristics such as wear resistance at the interface **332**. Further, as described above, selected embodiments of the grid connection structure **300** are less expensive to manufacture due in part to a reduction in an amount of gold used in interface layers.

FIG. 4 shows a chip assembly **400**. A chip package **410** is shown mounted to an adjacent circuit board **420**. In one embodiment, as shown in FIG. 4, a ball grid array **430** forms a number of input/output connections located between the chip package **410** and the circuit board **420**. In one embodi-

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ment, an underfill **440** is further included between the chip package **410** and the circuit board **420**.

FIG. 5A shows a grid connection structure **500** during a manufacturing process. A portion of a chip package **502** is shown with an electrical connection structure **520**. In one embodiment, the electrical connection structure **520** is located within an opening **504** in the chip package **502**. In one embodiment, the electrical connection structure **520** includes a metallic connection surface, for example a copper or copper containing surface. Further shown in FIG. 5A are interface layers **510**. A first layer **512**, a second layer **514**, and a third layer **516** are shown in FIG. 5A.

In one embodiment the first layer **512** includes nickel. In one embodiment the first layer **512** includes nickel and phosphorous. In one embodiment, the nickel in the first layer **512** is deposited on the electrical connection structure **520** using electroless deposition techniques. In one embodiment, the electroless deposition uses a chemical reaction to deposit the first layer **512**, which results in an alloy of nickel and phosphorous deposited as the first layer **512**. In one embodiment, the first layer is deposited to a thickness of between 5 and 8  $\mu\text{m}$ .

In one embodiment, the second layer **514** includes palladium. In one embodiment, the second layer includes palladium and phosphorous. In one embodiment, the palladium in the second layer **514** is deposited on the first layer **512** using electroless deposition techniques. In one embodiment, the electroless deposition uses a chemical reaction to deposit the second layer **514**, which results in an alloy of palladium and phosphorous deposited as the second layer **514**.

In one embodiment, the second layer **514** is deposited to a thickness of approximately 30-100 nm. In one embodiment, the second layer **514** is substantially amorphous on a nanometer scale dimension. In one embodiment, the amorphous microstructure is substantially non-porous. A non-porous microstructure provides an advantage of a continuous barrier layer over underlying structure such as the first layer **512**. Continuous, or non-porous layers help to prevent corrosion of underlying structure such as nickel in an embodiment of the first layer **512**.

In one embodiment, the third layer **516** includes gold. In one embodiment, the gold in the third layer **516** is deposited on the second layer **514** using electroless deposition techniques. In one embodiment, the electroless deposition uses a gold cyanide solution to provide a chemical reaction that deposits the gold in the third layer **516**. In one embodiment, the third layer **516** is deposited to a thickness of approximately 50-80 nm. FIG. 5B shows a close up view of a microstructure of the interfacial layers **510** as shown at the processing stage in FIG. 5A.

One advantage of deposition of a palladium second layer **514** between deposition of a gold third layer **516** and first layer **512** includes reduced corrosion. When a gold cyanide chemical deposition is used over nickel, the nickel tends to corrode and degrade quality in the interfacial layers **510**. In contrast, electroless deposition of a palladium layer **514** over the nickel layer **512** does not lead to appreciable corrosion. Further, the palladium second layer **514** serves as a barrier layer during the gold third layer deposition, thus improving quality in the interfacial layers **510**.

FIG. 5C shows a further stage of processing of the grid array connection structure **500**. A solder structure **530** is deposited onto the interfacial layers **510** and the grid array connection structure **500** is reflowed to provide the structure as shown in FIG. 5C. In one embodiment, the solder structure **530** includes a solder ball, such as for use in a ball grid array. One of ordinary skill in the art, having the benefit

of the present disclosure will recognize that embodiments having other solder structures such as pads, or other solder geometries are also within the scope of the invention. After the reflow process, a new interfacial region **540** is created due to material transport such as diffusion and chemical reactions taking place in the grid array connection structure **500**.

FIG. **5D** shows a microstructure of the interfacial region **540** after reflow. A solder portion **550** is shown, that includes lead free solder in one embodiment. In several electronic device designs, lead free solder is being used for attachments such as chip package attachment to an adjacent circuit board. There are a number of reasons to use lead free solders, including environmental concerns to reduce lead waste. Although environmental concerns are addressed using lead free solder, other challenges arise in manufacturing and design, such as increased hardness and possible brittle failure of some lead free solders. In one embodiment, the lead free solder **550** includes a SnAgCu solder composition. In one embodiment, the SnAgCu solder includes Sn3.0 Ag0.5 Cu. In one embodiment, the SnAgCu solder includes any solder in a range between Sn3.0-4.0 Ag0.5 Cu where numeric values indicate percent by mass in the solder.

FIG. **5D** also shows a first layer **542** which corresponds to the nickel first layer **512** discussed above. A second layer **544** is shown over the first layer **542**. A third layer **546** is located over the second layer **544**, and a fourth layer **548** is shown located between the third layer **546** and the solder portion **550**.

In one embodiment, the first layer **542** is substantially the same composition as the first layer **512** before the reflow process. Similar to embodiments described above, in one embodiment, the first layer **542** includes nickel. In one embodiment, the first layer includes nickel and phosphorous, as deposited in a an electroless deposition method.

In one embodiment, the second layer **544** includes nickel, tin, and phosphorous (NiSnP). One of ordinary skill in the art, having the benefit of the present disclosure will recognize that while discrete layers and chemistries are labelled in the present figures for illustrative purposes, concentration gradients of various layer chemistries may not be discrete. In some embodiments, a concentration profile will vary across a layer as shown in the Figures due to reaction variables or transport kinetics, etc.

In one embodiment, the third layer **546** includes tin, nickel, copper, and phosphorous (SnNiCuP). In one embodiment the third layer **546** is an intermetallic layer formed during the reflow process. In one embodiment, the third layer **546** is located approximately where the second layer **514** from FIG. **5A** was located before the reflow process. In one embodiment, the third layer **546** is formed by replacement of palladium by SnCu groups. In one embodiment, the palladium (Pd) from the second layer **514** diffuses into the solder portion **550** during the reflow process, leaving behind the third layer **546**.

Although elements that are present are indicated in the description of the layers, the exact stoichiometry varies in some embodiments, unless otherwise noted. For example, although description of the third layer indicates that in one embodiment SnCu replaces palladium (Pd) during reflow, it is not necessary in all embodiments for only one atom of tin and one atom of copper to exactly replace one atom of palladium.

In one embodiment, the fourth layer **548** includes copper, nickel, and tin. In one embodiment the fourth layer **548** is an intermetallic layer formed during the reflow process. In one embodiment the fourth layer includes crystalline grains of

(CuNi)<sub>6</sub>Sn<sub>5</sub>. In embodiments with crystalline grains, the stoichiometry of the grains is specific as indicated by the chemical notation (CuNi)<sub>6</sub>Sn<sub>5</sub>. In one embodiment the crystalline grains of (CuNi)<sub>6</sub>Sn<sub>5</sub> are elongated as indicated in FIG. **5D**. In one embodiment, elongated grains are formed due to the presence of the second layer **514** in the structure prior to reflow. In one embodiment, palladium controls the diffusion of nickel during reflow, resulting in a more elongated and finer grain structure than if the second layer **514** had not been present. One advantage of grain structures in the fourth layer **548** as described above includes improved mechanical properties such as hardness and tensile strength, etc. that result in a more robust grid connection structure **500**.

FIG. **6** shows one example of a method of forming a grid array connection structure as described in embodiments above. In one operation, a nickel layer is formed over at least one electrical connection surface. In another operation, a palladium layer is formed over the nickel layer. In another operation, a gold layer is formed over the palladium layer. Additional method operations follow in selected embodiments as described above. For example, in a land grid array example, a pin is brought into contact with the gold layer, and improved properties such as hardness and wear resistance provide a more robust land grid array connection. In another example, a solder structure is further formed over the gold layer, and the structure is reflowed to create a ball grid array structure. Improved properties such as corrosion resistance and grain structure provide a more robust ball grid array structure.

An example of an information handling system using processor chips is included to show an example of a higher level device application for the present invention. FIG. **7** is a block diagram of an information handling system **700** incorporating at least one electronic assembly **710** utilizing an input/output connection structure in accordance with at least one embodiment of the invention. In one embodiment, the input/output connection includes a land grid array connection. In one embodiment, the input/output connection includes a ball grid array connection.

Information handling system **700** is merely one example of an electronic system in which the present invention can be used. In this example, the information handling system **700** includes a data processing system that includes a system bus **702** to couple the various components of the system. System bus **702** provides communications links among the various components of the information handling system **700** and can be implemented as a single bus, as a combination of busses, or in any other suitable manner.

Electronic assembly **710** is coupled to system bus **702**. Electronic assembly **710** can include any circuit or combination of circuits. In one embodiment, electronic assembly **710** includes a processor **712** which can be of any type. As used herein, "processor" means any type of computational circuit, such as but not limited to a microprocessor, a microcontroller, a complex instruction set computing (CISC) microprocessor, a reduced instruction set computing (RISC) microprocessor, a very long instruction word (VLIW) microprocessor, a graphics processor, a digital signal processor (DSP), or any other type of processor or processing circuit.

Other types of circuits that can be included in electronic assembly **710** are a custom circuit, an application-specific integrated circuit (ASIC), or the like, such as, for example, one or more circuits (such as a communications circuit **714**) for use in wireless devices like cellular telephones, pagers,

portable computers, two-way radios, and similar electronic systems. The IC can perform any other type of function.

Information handling system **700** can also include an external memory **720**, which in turn can include one or more memory elements suitable to the particular application, such as a main memory **722** in the form of random access memory (RAM), one or more hard drives **724**, and/or one or more drives that handle removable media **726** such as compact disks (CD), digital video disk (DVD), and the like. Examples of main memory **722** include dynamic random access memory (DRAM), synchronous dynamic random access memory (SDRAM), flash memory, static random access memory (SRAM), etc.

Information handling system **700** can also include a display device **716**, one or more speakers **718**, and a keyboard and/or controller **730**, which can include a mouse, trackball, game controller, voice-recognition device, or any other device that permits a system user to input information into and receive information from the information handling system **700**.

Devices and methods described above provide a number of advantages. For example, land grid array structures are described with improved mechanical properties such as hardness and abrasion resistance. Land grid array structures are also shown that are less expensive to manufacture due to reductions in material cost such as gold. Ball grid array structures are also described with improved resistance to corrosion during fabrication. Ball grid array structures are also described with improved mechanical properties to provide improved joint interface strength in solder joints such as lead free solder joints.

Although selected advantages are detailed above, the list is not intended to be exhaustive. Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that any arrangement which is calculated to achieve the same purpose may be substituted for the specific embodiment shown. This application is intended to cover any adaptations or variations of embodiments described above. It is to be understood that the above description is intended to be illustrative, and not restrictive. Combinations of the above embodiments, and other embodiments will be apparent to those of skill in the art upon reviewing the above descrip-

tion. The scope of the invention includes any other applications in which the above structures and fabrication methods are used. The scope of the invention should be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.

What is claimed is:

1. A semiconductor chip connection structure comprising:
  - a metallic connection structure;
  - a first layer including nickel (Ni) on the metallic connection structure;
  - a solder structure;
  - an intermetallic layer including copper (Cu), nickel (Ni) and tin (Sn) between the first layer including nickel (Ni) and the solder structure; and
  - a second layer including tin (Sn), nickel (Ni), copper (Cu) and phosphorous (P) between the intermetallic layer and the first layer.
2. The semiconductor chip connection structure of claim 1, wherein the intermetallic layer includes crystalline grains.
3. The semiconductor chip connection structure of claim 2, wherein the crystalline grains are elongated.
4. The semiconductor chip connection structure of claim 1, wherein the intermetallic layer includes (CuNi)<sub>6</sub>Sn<sub>5</sub>.
5. The semiconductor chip connection structure of claim 1, wherein the first layer including (Ni) further includes phosphorous (P).
6. The semiconductor chip connection structure of claim 1, wherein the solder structure includes tin (Sn), silver (Ag) and copper (Cu).
7. The semiconductor chip connection structure of claim 1, wherein the metallic connection structure comprises copper (Cu).
8. The semiconductor chip connection structure of claim 1, wherein the solder structure includes a ball grid array solder ball.
9. The semiconductor chip connection structure of claim 1, wherein the chip connection structure provides an input/output connection between a chip package and a circuit board.
10. The semiconductor chip connection structure of claim 1, wherein the solder structure includes palladium (Pd).

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